Autonomous Observations of the Upper Ocean Stratification and Velocity Fields About the Seasonally-Retreating Marginal Ice Zone

John M. Toole, Richard A. Krishfield, Sylvia T. Cole,
Fredrik T. Thwaites and Mary-Louise Timmermans

Acquisition of Ice-Tethered Profilers with Velocity (ITP-V) Instruments as a Contribution to the Marginal Ice Zone DRI

John M. Toole, Richard A. Krishfield and Fredrik T. Thwaites
Mail Stop 21, WHOI
Woods Hole, MA 02543
PO Box 208109
New Haven, CT 06520-8109
phone: (508) 289-2531 (JMT) fax: (508) 457-2181 email: jtoole@whoi.edu
phone: (508) 289-2489 (RAK) fax: (508) 457-2181 email: rkrishfield@whoi.edu
phone: (508) 289-3805 (STC) fax: (508) 457-2181 email: scole@whoi.edu
phone: (508) 289-3351 (FTT) fax: (508) 457-2181 email: fthwaites@whoi.edu
phone: (203) 432 3167 (MLT) fax: (203) 432-3134 email: mary-louise.timmermans@yale.edu

Award Number: N00014-12-1-0140
Award Number: N00014-12-1-0799
http://www.whoi.edu/itp

LONG-TERM GOALS

Our research seeks to build understanding of upper-ocean processes and ice-ocean interactions in the polar oceans (Arctic and Southern Ocean). Particular areas of focus include ice-ocean exchanges of momentum, heat and salt, mixed layer variability including layer deepening, vertical entrainment and restratification processes, and internal wave dynamics and associated turbulent mixing. With better understanding of the physical processes, improved model parameterizations and in turn, model predictions will result.

OBJECTIVES

We seek to observe upper-ocean variability and ice-ocean interactions at a set of 4 sites spanning the seasonal retreat of the MIZ. The current projects are a contribution to the Marginal Ice Zone DRI. A supporting objective is to continue to improve the performance and data reduction procedures for the primary instrument system we will employ in the MIZ DRI: the Ice-Tethered Profiler with Velocity (ITP-V).

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **2012**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Autonomous Observations of the Upper Ocean Stratification and Velocity Fields About the Seasonally-Retreating Marginal Ice Zone**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **WHOI Woods Hole, MA 02543 PO Box 208109 New Haven, CT 06520-8109**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**3**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

Our contribution to the MIZ DRI will utilize Ice-Tethered Profilers equipped with a velocity sensor (ITP-V). Four ITP-V's will be deployed in spring 2014 from air-supported ice camps along a ~meridional line north of Alaska spanning a ~300 km distance that is expected to transition from near-full ice cover to near-open water over the summer melt season. Being mounted in and supported by ice floes, the ITP-V array will follow wind/current displacements of the ice while sampling the seasonal evolution of the water column below the ice. The ITP-Vs will be programmed to profile the upper ~200 m of the water column at 3-h interval and return ocean temperature, conductivity and velocity profile observations (the latter by combining relative velocity data with buoy drift estimates based on GPS fixes) as well as make periodic observations of the turbulent heat, salt and momentum fluxes just below the ice-ocean interface.

The ITP-V array will be augmented with Ice-Mass-Balance Buoys sampling the evolving sea ice thickness, Arctic Ocean Flux Buoys that will continuously sample the surface layer turbulent eddy motions, and acoustically-tracked profiling floats and gliders that will observe the upper ocean around the ITP-V array.

WORK COMPLETED

Our research project is partitioned into two components: a DURIP award funding acquisition/assembly of 4 ITP-V instrument systems to be used in the main MIZ DRI field experiment and a science award funding on-going development and testing of the ITP-V instrument and the fieldwork and analysis of the ITP-V data that will derive from the program. Present focus is on completion of one analysis project based on prototype ITP-V data and constructing two second-generation ITP-V systems. Cole and Thwaites have taken the lead analyzing data from the prototype ITP-V system (funded by the National Science Foundation and WHOI internal grants). Work by the latter led to a redesign of the acoustic transducer array of the "travel-time" current meter (Nobska MAVS) used on the ITP-V instrument. The new sensor head and associated welding jig have been designed, as have the custom endcaps (two of which have now been fabricated). The purchase orders for the MAVS and SBE CTD's were sent out in May. We have in hand the transducers, polyurethanes, connectors and cable needed to build the MAVS transducer arrays. The MAVS circuits with a low-noise switching power supply and the new attitude heading reference system have been designed and assembled. The sensor stings will be welded and the endcaps with circuit card supports sent to Seabird Electronics, Inc. for CTD installation and calibration. While the endcaps are at Seabird, Thwaites will be potting the transducer modules and wiring the sensor stings. After we receive the endcaps back from SBE, he will assemble, test, and calibrate the MAVS sensors. Once the underwater units are complete, we will be testing the units in a local well facility with the plan to deploy one of these systems in the Arctic for final validation in summer 2013. In association with our NSF-funded ITP program, progress has also been made on improvements to the data telemetry equipment of the ITP system. Specifically, a faster inductive modem has been integrated with the system and plans are in hand for a more capable surface buoy controller that will be able to compress the ITP data stream (reducing power and saving telemetry costs).

Cole's work with the prototype ITP-V data set has greatly refined our data reduction procedures and resulted in a scientific manuscript that is poised to be submitted to the Journal of Physical Oceanography.

RESULTS

Extracting from the manuscript of Cole et al., 2012 (Ekman veering, internal waves, and turbulent fluxes observed under Arctic sea-ice, J. Phys. Oceanogr., in preparation): The ice-ocean system is investigated on inertial to monthly timescales using winter 2009-2010 observations from the first Ice-Tethered Profiler (ITP) equipped with a velocity sensor (ITP-V). Fluctuations in ice velocity, ocean velocity at 7 m depth, and surface winds were correlated. Observed ocean velocity was primarily directed to the right of ice velocity and spiraled clockwise while decaying with depth through the surface mixed layer. Inertial and tidal motions of the ice and in the underlying ocean were observed throughout the record. Periods of elevated internal wave activity were associated with changes to stratification primarily within surface layer. Just below the ice-ocean interface, direct estimates of the turbulent vertical heat, salt, and momentum fluxes and the turbulent dissipation rate were obtained. Turbulent eddies were anisotropic with diminished vertical velocity fluctuations. The production and dissipation of turbulent kinetic energy were largely balanced. Turbulent momentum flux was correlated with the ice-ocean velocity difference, allowing a drag coefficient to be estimated. The ice-ocean drag coefficient was elevated for certain directions of the ice-ocean shear, implying ice topography that was dominated by ridges. Turbulent heat flux was primarily upward, while salt flux alternated in sign, likely due to periods of brine rejection during ice formation (causing downward salt flux) and internal wave mixing and vertical entrainment of saltier waters (inducing upward salt flux). Analyses of this and future ITP-V data sets will advance understanding of ice-ocean interactions and their parameterizations in numerical models.

IMPACT/APPLICATIONS

The research and engineering supported by these grants will move the ITP-V instrument to operational status.

RELATED PROJECTS

The present project has strong ties to the WHOI Ice-Tethered Profiler program that contributes to the Arctic Observing Network. See www.whoi.edu/itp.